Research Brief for
DOE/IHEA Process Heating Materials Forum

Research Title: Advanced Wrought Alloys with Improved High Temperature Performance for Waste Heat Recovery Systems

Industry Need: There is a need for increased life of waste heat recovery systems, including recuperators and other heat-exchangers. Increases in component life come from the combination of increased high-temperature strength and oxidation resistance, as well as increased resistance to aging affects and thermal cycling. Modifications of composition or processing of existing alloys can provide near-term cost-effective solutions, while coatings or design of significantly different alloys can offer long-term solutions.

Existing Research: ORNL has been involved in cutting-edge high-temperature materials work for nuclear or fossil energy heat-exchanger materials for 15-20 years, and has more recently become a leader in developing heat- and corrosion-resistant alloys for advanced compact heat-exchanger technology applicable to industrial gas turbines, microturbines, and fuel-cell applications. ORNL has developed low-cost high-performance stainless steels and stainless alloys with significantly improved high-temperature strength and creep-rupture resistance, in some cases approaching the performance usually found in Ni-based superalloys. Previous and existing work take advantage of ORNL's unique capabilities, experience and expertise in alloy design and development, particularly designing and producing new microstructural behavior as the basis for high-temperature properties improvements. ORNL has an enormous data base on processing-induced and aging-induced microstructures (phases, distribution, stability and microcomposition), and unique methods for understanding and applying such information to produce "engineered microstructures." One such example of this method is using modified alloy compositions and processing to make thin-foils (fine-grained) of 347 stainless steel much more creep resistant by enhancing the dispersion and stability of fine matrix precipitates for strength (ie. NbC), and eliminating coarse grain boundary precipitates that degrade properties (ie. Fe-Cr sigma phase). ORNL has experience at making new alloys as lab-scale heats and directly scaling up such alloys into commercial processing. This new project should directly benefit various related research programs at ORNL.

Proposed Activity: The additional research needed to define the needs of industrial waste heat recovery systems would be strategic analysis of current alloys and components that fail or degrade in service, together with those same materials in the fresh, as-processed state. Carefully microstructure and properties analysis of such components provides an exact definition of the problem. ORNL possess unique experience and expertise at analyzing such microstructural information to clearly define the mechanisms responsible for failure, including combinations of mechanism affecting both mechanical properties and corrosion behavior, which then guide finding efficient and effective solutions. ORNL has equipment and expertise to conduct lab-scale alloy casting, processing (including welding) and properties testing related to component behavior.

ORNL also has experience and success at working with the component and equipment end-users as well as component and materials producers and manufacturers to quickly translate lab analysis and lab-scale testing into trial component production for testing in the actual environments. ORNL has had particular success at doing unique alloy development and modification and circumvents normal properties trade-offs (ie. higher strength – lower ductility) to enable dramatic improvements in the properties that cause final failure, like creep-rupture, creep-fatigue, fatigue or severe thermal cycling. ORNL can work well with individual companies as well as groups of companies with similar problems or with consortia. ORNL has experience and capabilities for working with materials used at temperatures ranging from 600°C to over 1100°C.

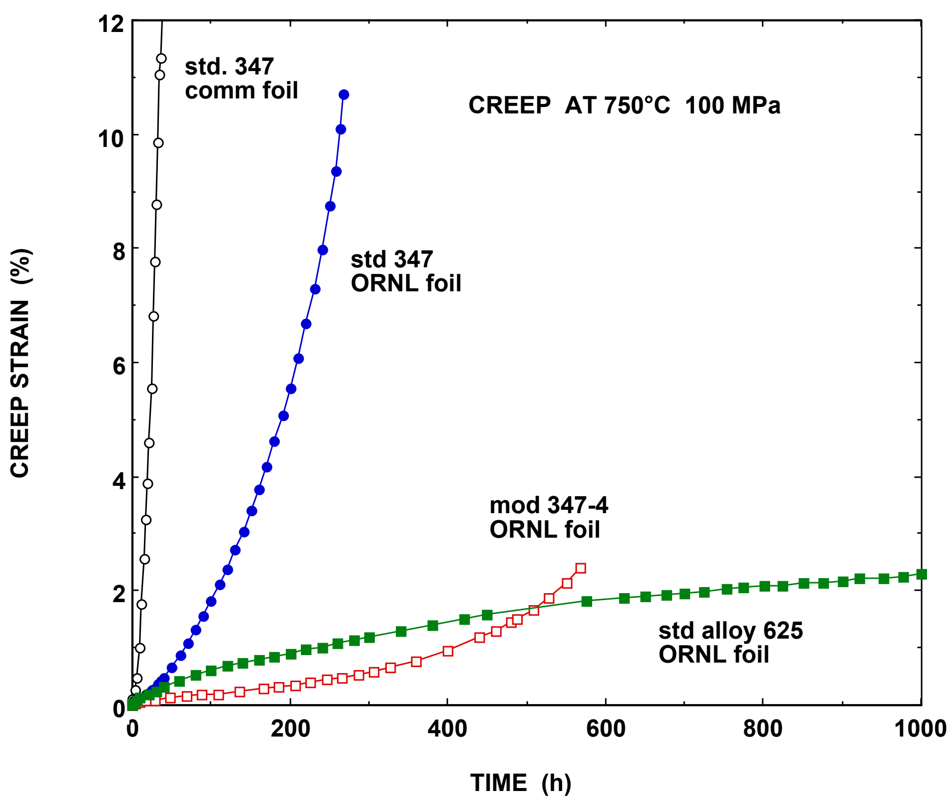

Fig. 1 – ORNL creep rupture testing of 0.004 inch thick foil specimens in air.

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